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Difference in Density of Fiber Bundles Exposed on Surface of Asbestos-Containing Materials

with the Aim to Reduce Time Necessary for Visual Observation

Hiroshi Asakura[1], Mikio Kawasaki[2], Kazuyuki Suzuki[2], Kei Nakagawa[1], Yoichi Watanabe[2]

[1]Nagasaki University, Nagasaki, Japan

[2]Center for Environmental Science in Saitama, Saitama, Japan
[1]asakura_hiroshi@yahoo.co.jp

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Abstract

It is possible that asbestos-containing materials (ACMs) are contained in construction and demolition waste (CDW) that is transported to an intermediate treatment facility. Therefore, a rapid method of detecting asbestos fibers at an intermediate treatment facility for CDW is required. Although a visual observation method has been developed for rapid determination, the time required to determine should be shortened further. If asbestos fibers on a certain part of the surface of CDW particles could be detected visually and observation of the other areas could be omitted, the time necessary for the observation can be shortened. In this study, the determination error rates for a certain part of the surface and the entire surface were estimated. A CDW particle whose surface remained intact when the construction material was produced, was classified as an intact-surface CDW particle. A CDW particle that chipped off when the construction material was demolished or shredded, was classified as a broken-surface CDW particle. Observation of only the broken surface yielded similar results to observation of the entire surfaces of non-ACMs and ACMs. For non-ACMs, the determination error rate for observation of one-half of the broken surface was 1.6%, whereas that for observation of the entire broken surface was 2.2%. For ACMs, the determination error rate for observation of one-half of the broken surface was 0.16%, whereas that for observation of the entire broken surface was 0%. From the obtained error rates, it was found that the time necessary for observation can be shortened.

Keywords

Asbestos; Fiber Bundle; Construction and Demolition Waste; Visual Observation; Sorting; Error Rate

Introduction

Materials containing > 0.1 w% asbestos are regarded as asbestos-containing materials (ACMs) in Japan. Solid waste containing > 0.1 w% asbestos is also regarded as asbestos-containing waste in Japan and EU. As asbestos-containing waste from building demolitions has to undergo special treatment prior to recycling or final disposal, the demolition of buildings and the sorting of waste materials are conducted after checking for asbestos content in the construction materials (according to ISO, EPA, or JIS). However, as solid waste is usually a mixture of materials, it is possible that ACMs are contained in construction and demolition waste (CDW) that is transported to an intermediate treatment facility. In addition, the presence of ACMs in waste generated following the Great East Japan Earthquake cannot be avoided. Therefore, a rapid method of detecting asbestos fibers at an intermediate treatment facility for CDW is required.

The main topics of previous studies on waste materials and asbestos included asbestos content in waste sludge (Bishop et al., 1985), particle emission from solid waste (Tadasa et al., 2011), and detoxification of asbestos in solid waste (Plesciaa et al., 2003; Min et al., 2008; Zaremba and Peszko, 2008; Gualtieria et al., 2011; Osada et al., 2013; Radvanec et al., 2013). As far as we know, there have been no studies on the sorting of ACMs and non-ACMs. To realize sorting, it is necessary to understand the physical and chemical properties of waste (e.g., density and magnetic property) and to determine whether the waste contains asbestos fibers. The purpose of studies on the identification of asbestos (Ruud et al., 1969; Pooley, 1975; Taylor et al., 1984; Bard et al., 1997) is to develop

an accurate method of asbestos analysis. Bassania et al. (2007) reported the use of remote sensing to detect asbestos in roofing sheets, which enabled scanning of ACMs by batch in large urban areas. Some studies have employed an advanced analyzer with high accuracy.

Because it takes a long time to identify asbestos fibers by conventional laboratory methods, such as those adopted by ISO, those methods are unsuitable for CDW in intermediate treatment facilities. Currently, one of the major sorting methods used at intermediate treatment facilities for CDW is manual sorting by visual observation. Saitama Prefecture has developed a rapid method of asbestos fiber determination by visual observation (Saitama Japan Industrial Waste Association, 2011). Asakura et al. (2013) investigated the determination accuracy and time required for ACM determination by visual observation. After participating in a short training course on ACM determination, persons who did not have any prior knowledge of such a method were able to determine ACMs in CDW by visual observation. However, although this method has been considered a rapid one at present, it still takes a long time (26 s particle^{-1}); it is necessary to shorten the time further. Asakura et al. (2013) found that there were some sections of CDW particles where fibers assumed to be asbestos can be identified easily by visual observation. If asbestos fibers were determined only on a certain part of the surface of CDW particles by visual observation and the observation of other parts were omitted, the time necessary for visual observation could be shortened.

In this study, the surface of a CDW particle was divided into sections, and the density of fiber bundles assumed to be asbestos exposed on the each section was estimated by visual observation. CDW particles were classified as ACMs and non-ACMs on the basis of the measured asbestos content. From the above, the determination error rate when the entire surface of CDW particles was examined visually and that when only a certain part was examined, was calculated.

Theory

Intact and Broken Surfaces

A CDW particle whose surface remained intact when the construction material was produced, was classified as an intact-surface CDW particle, whereas a CDW particle that chipped off when construction materials were demolished or shredded, was classified as a broken-surface CDW particle. Regarding a sheet of construction material, the largest surface (and the reverse side) should be considered an intact surface. In most cases, breaks were generated in the vertical direction of the largest surface (Fig. 1). Therefore, an intact surface would hardly be chipped off in the first stage of demolition or shredding. Whether a CDW particle from a sheet of construction material has an intact or a broken surface can easily be determined by visual observation because an intact surface will have the original characteristics of a construction material whereas a broken surface will be rough.

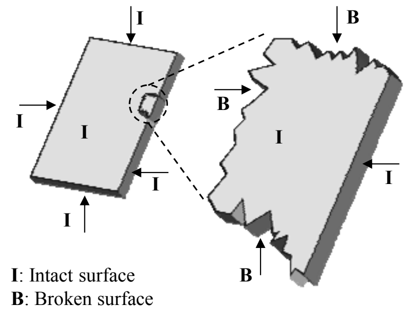

FIG. 1 INTACT AND BROKEN SURFACES OF SHEETLIKE CDW

Difference in Density of Fiber Bundles Between Intact and Broken Surfaces

Suppose that the density of asbestos fiber bundles exposed on the surface of a particle of CDW differs from area to area, i.e., there are areas with many bundles (M) and there are those with few bundles (F). If the density of asbestos fibers in area M is determined by visual observation and the observation of area F could be omitted, the time necessary for visual observation can be shortened. Asakura et al. (2013) found that there were more fibers assumed to be asbestos on a broken surface than on an intact surface, as determined from experience of visual observation. Using the measured average density of fiber bundles on an intact surface I_{ave} (number of bundles cm^{-2}) and that on a broken surface B_{ave} (number of bundles cm^{-2}) of CDW particles, the density ratio B_{ave}/I_{ave} can be calculated. When the ratio is large, the result of determination by observation of only the broken surface will be similar to that by observation of the entire surface.

Difference in Density of Fiber Bundles on Broken Surface

Suppose that the density of asbestos fiber bundles exposed on the broken surface of a particle of CDW does not differ from area to area. If the density of

asbestos fibers on a part of the broken surface is determined by visual observation and the observation of other parts could be omitted, the time necessary for visual observation can be shortened. Using the calculated density of fiber bundles on the broken surface B (number of bundles cm^{-2}) on each section of a CDW particle, the difference in density depending on the section examined can be estimated. When the difference is small, the result of determination by observation of only half of the broken surface will be similar to that by observation of the entire broken surface. By this method, we can reduce the time necessary for visual observation by half, i.e., from 26 s $particle^{-1}$ (only on the broken surface) obtained in past research by Asakura et al. (2013) to 13 s $particle^{-1}$.

An observer can set one-half of the broken surface optionally. Specifically, assuming a disk form of a CDW particle (the ellipse area is the intact surface and the side is the broken surface), the ellipse is divided by a straight line passing through the center, and only the broken surface that came into contact with one side of the arc of the ellipse should be observed. The straight line can be drawn optionally. In this study, one-half of the broken surface was set randomly. The broken surface was divided into 12 sections on the ellipse of a CDW particle similarly to an analog clock. Six of the 12 sections were chosen optionally.

Materials and Methods

Facilities and Waste Samples

Waste samples were collected from an intermediate treatment facility in Japan (X) where CDW was crushed and recyclable materials were recovered. The treatment flows at demolition sites and intermediate treatment facility X is shown in Fig. 2. Presorted ACMs were bagged (A) at demolition sites. Other waste construction materials, i.e., non-ACMs, were manually presorted into recyclable materials (e.g., stones and metals) and mixtures of other materials (hereafter, “mixture”), as shown in Fig. 2. The bagged ACMs, the recyclable materials, and the mixture were transported to facility X. The bagged ACMs (A) were stored and brought to a landfill site. The mixture was manually presorted into recyclable materials and other residues. The residues were sieved through a 40 mm mesh vibrating sieve. Particles that remained on the sieve (B) were recycled or deposited at a landfill site, and fine particles that passed through the sieve were also deposited at a landfill site. A and B were collected. Only sheetlike CDW particles were collected from B. However, there were few particles other than the sheetlike particles on the sieve. We thought that large particles were presorted into recyclable materials as stones, bricks, or blocks before sieving.

In order to identify particles containing asbestos, A and B were mixed. After mixing, 127 particles were sampled randomly. Dust on the particles was brushed off and the particles were washed with tap water. Then, the particles were numbered using an oil-based marking pen; hereafter, referred to as “CDW_P”. All of the CDW_P’s were sheetlike. The number was written on the largest surface of each CDW_P. The largest surface (and the reverse side) was considered as intact because it was smoother than the side surface. Similarly, the side surface was considered a broken surface because it was rough. Therefore, all considerations of the intact and broken surfaces were subjective.

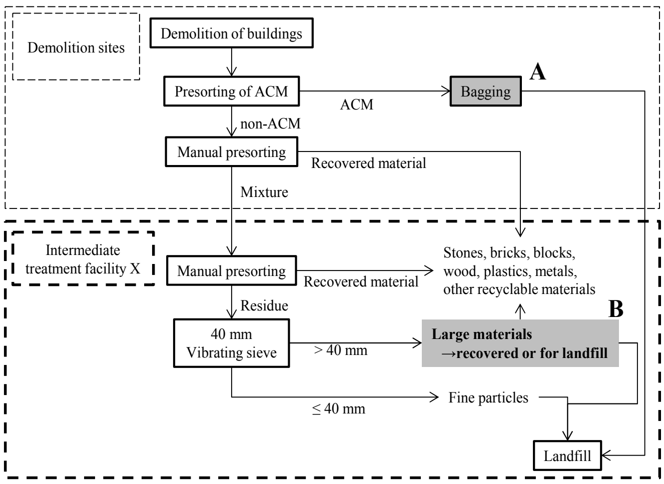

FIG. 2 TREATMENT FLOW AT DEMOLITION SITES AND INTERMEDIATE TREATMENT FACILITY X. SAMPLING POINTS ARE ALSO SHOWN (A AND B).

Sample Characteristics

The dimensions (i.e., shortest, medium, and longest sides) and weight of a CDW_P were measured.

Experimental Methods

1) Main Points for Determination of ACMs by Visual Observation

The asbestos fibers in a CDW_P were identified as follows: first, the fibers on the surface of a CDW_P were identified and then it was determined whether such fibers were asbestos or not. For the determination of asbestos fibers, individual characteristics of the fibers were examined (Asakura et al., 2013), i.e., the asbestos fibers should be fascicular and irregular in shape.

Therefore, an independent and regularly shaped fiber is not asbestos (e.g., cotton or glass wool).

2) *Instruments for Visual Observation*

As asbestos fibers in a CDW$_P$ form bundles, they can usually be easily identified by the naked eye. However, as there are also thin bundles, we used a loupe (15X magnification) to improve determination accuracy. Images of the fiber bundles were taken using a portable digital microscope, 3R-MSV330 ViewTy (10X magnification).

3) *Visual Observation of Asbestos Fiber on Intact and Broken Surfaces*

The experimenter was in his twenties and did not have any knowledge of the determination of asbestos fibers. We showed to the experimenter the above-mentioned characteristics of asbestos fibers using photographs. Then, the training for visual observation with a loupe was conducted for 10 minutes using samples that had typical asbestos fibers. The entire training course took approximately 30 minutes. After that, the visual observation experiment was performed as follows.

A CDW$_P$ was chosen, its surface was observed using a loupe, and the number of fiber bundles presumed to be asbestos was counted. The bundles were counted because the number of fibers was too large to be counted. In regard to the intact surface, a CDW$_P$ was placed on a laboratory table in the direction where the number was readable. Coordinates were set on the left side of the particle as the y-axis and the bottom side as the x-axis. The position of a grid (1 x 1 cm^2) in the coordinates and the number of fiber bundles assumed to be asbestos on that grid were recorded (Fig. 3). In regard to the broken surface, the direction was set like an analog clock and the section of the direction (within the range of an hour) and the number of fiber bundles assumed to be asbestos on that section were recorded (Fig. 4).

In this study, a CDW$_P$ is regarded as an ACM once fibers assumed to be asbestos are found. Similarly, a CDW$_P$ is regarded as a non-ACM when fibers assumed to be asbestos cannot be found. In this study, determination error is defined as the "determination of CDW$_P$ containing asbestos at > 0.1 w% as a non-ACM" and "determination of CDW$_P$ containing asbestos at < 0.1 w% as an ACM." However, the determination is based on not the asbestos content but the existence of fibers assumed to be asbestos, as asbestos content cannot be determined by visual observation.

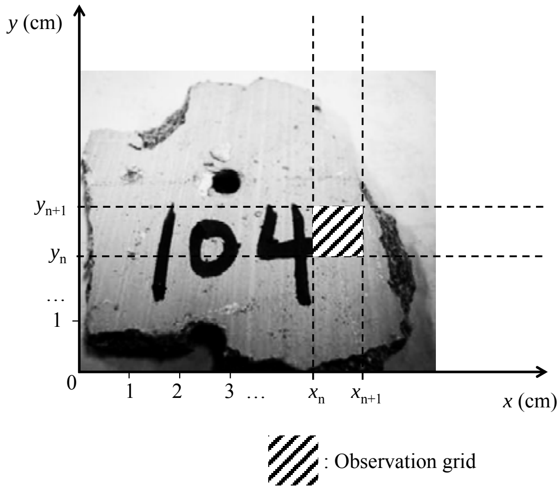

FIG. 3 COORDINATE SETTING FOR VISUAL OBSERVATION OF INTACT SURFACE

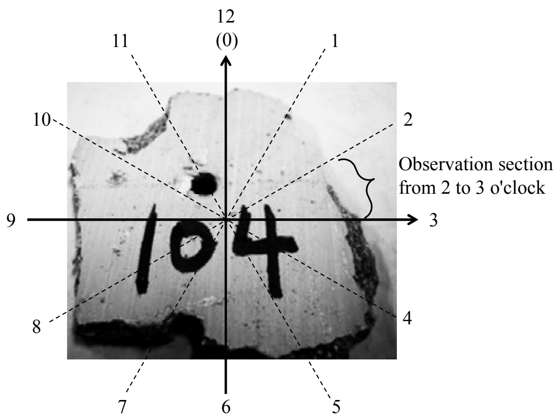

FIG. 4 DIRECTION SETTING FOR VISUAL OBSERVATION OF BROKEN SURFACE

4) *Asbestos Content*

Asbestos content in a CDW$_P$ was measured after visual observation. The target minerals for measurement were chrysotile, amosite, crocidolite, tremolite, actinolite, and anthophyllite. Qualitative and quantitative analysis were conducted by transmission electron microscopy (EPA600/R-93/116) and the minimum determination limit was 0.1 w%. However, it was unknown whether the observed fibers were indeed asbestos or not because fiber bundles were identified only by visual observation.

Experimental Results

Sample Characteristics and Asbestos Content

The longest, medium, and shortest sides of a particle

were 6.2 cm, 4.0 cm, and 1.2 cm on average, respectively, and the average weight was 67 g (n = 127). The number of samples in which the asbestos contents were < 0.1 w% (non-ACMs) was 89. The number of samples in which the asbestos contents were > 0.1 w% (ACM) was 38, and the minimum, average, and maximum contents were 7.0 w%, 12 w%, and 20 w%, respectively. Therefore, there were no samples with asbestos contents from 0.1 to 7 w%, and only samples with asbestos contents < 0.1 w% and from 7 to 20 w% were examined in this study. Chrysotile was detected in all of the ACM samples (Fig. 5), and crocidolite was also detected with only one sample (Fig. 6).

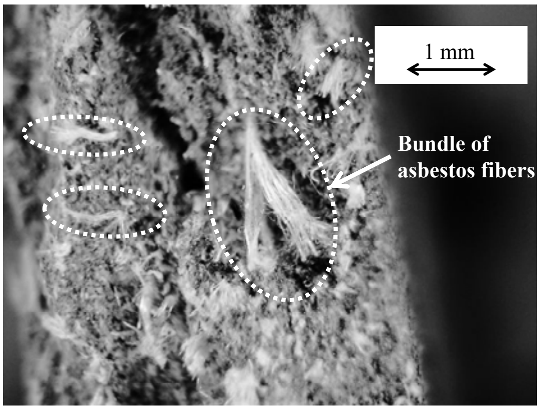

FIG. 5 OBSERVED BUNDLE OF FIBERS (SURFACE OF SAMPLE CONTAINING CHRYSOTILE AT 20 W%)

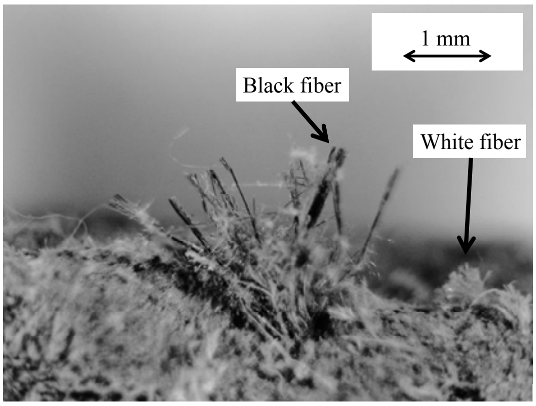

FIG. 6 OBSERVED BUNDLE OF FIBERS (SURFACE OF SAMPLE CONTAINING CHRYSOTILE AT 10 W% AND CROCIDOLITE AT 4 W%)

Density of Fiber Bundles

The average densities of fiber bundles assumed to be asbestos on the intact and broken surfaces of a CDW_P determined by visual observation are shown in Table 1. Surface area is needed to calculate the density of fiber bundles. An elliptic column that formed an ellipse with the medium and longest sides, and height of the shortest side of a sample particle was presumed for the form of each CDW_P. The average surface areas of all CDW_P's were 42.6 cm² for the intact surface (front and back sides) and 20.6 cm² for the broken surface, with a total of 63.2 cm². For non-ACMs, the average densities of fiber bundles (n = 89) were 0.0029 bundles cm⁻² for the intact surface and 0.0045 bundles cm⁻² for the broken surface. For ACMs, the average densities of fiber bundles (n = 38) were 0.15 bundles cm⁻² for the intact surface and 23 bundles cm⁻² for the broken surface. The densities of fiber bundles ranged from 0 to 7 bundles cm⁻² for the intact surface and showed no specific trend.

The densities of fiber bundles on the broken surface of ACMs (n = 38) determined by visual observation are shown in Table 2. There were many sections without the bundles in samples with a low asbestos content (7 w%, sample Nos. 1 and 2). However, there were sections without the bundles also in samples with an asbestos content of 15 w% such as sample No. 33. There were some sections with a smooth surface on the side, although the surface of the side of sheetlike CDW_P samples was considered as a broken surface in this study (a, shaded entries in Table 2; 3 samples, 5 sections). Although the density of bundles tended to be low on the section presumed to be that of the intact surface, the details are unclear because this is a rare case. The state in which the side surface was intact is shown in Fig. 1. Crocidolite was detected (4 w%) in sample No. 21.

TABLE 1 AVERAGE DENSITIES OF FIBER BUNDLES ON INTACT AND BROKEN SURFACES OF CDW_P DETERMINED BY VISUAL OBSERVATION

	Number of particles	Intact surface I_{ave}	Broken surface B_{ave}	Ratio B_{ave}/I_{ave}
	–	Number of bundles cm⁻²	Number of bundles cm⁻²	–
non-ACMs	89	0.0029	0.0045	1.5
ACMs	38	0.15	23	150

Discussion

Density of Asbestos Fiber Bundles on Intact and Broken Surfaces

The density ratios (B_{ave}/I_{ave}) are shown in Table 1. The ratio for non-ACMs was 1.5. Fiber bundles were hardly found in non-ACMs. Finding fiber bundles does not necessarily mean that the material contains asbestos, or a material with an asbestos content of < 0.1 w% is not necessarily an ACM, although the fibers on it are asbestos. In this way, determination error for non-ACMs occurred when the fibers found were assumed to be asbestos by visual observation. There

were two samples in which fiber bundles were found on only the intact surface and another two samples in which they were found on only the broken surface among 89 non-ACM samples. Therefore, the determination error rate for observation of the intact and broken surfaces was 4/89 = 0.045, and that for observation of only the broken surface was 2/89 = 0.022 (Table 3). Therefore, determination error rate for observation of only the broken surface is rather lower than that for observation of both the intact and broken surfaces.

TABLE 2 DENSITIES OF FIBER BUNDLES ON BROKEN SURFACE OF ACMS DETERMINED BY VISUAL OBSERVATION

	Asbestos content C (w%)	Density of fiber bundles on broken surface (number of bundles cm^{-2}) Section from upper to lower row o'clock											
		1	2	3	4	5	6	7	8	9	10	11	12
		2	3	4	5	6	7	8	9	10	11	12	1
1	7.0	1	1	0	0	0	0	0	3	0	0	0	1
2	7.0	0	0	0	1	0	0	2	1	1	0	0	0
3	10	45	45	18	18	21	32	39	36	25	9	13	41
4	10	3	0	6[a]	11	0	3	0	9	0	0	0	1
5	10	79	59	20	39	73	56	25	39	20	56	17	31
6	10	10	24	24	3	7	7	7	20	13	8	13	7
7	10	4	5	41	44	19	26	22	52	38	38	15	15
8	10	17	18	18	31	18	28	65	10	7	34	20	13
9	10	29	25	41	59	41	14	20	37	19	20	5	17
10	10	10	14	47	37	18	24	26	69	32	12	8	6
11	10	10	24	61	24	7	9	43	0	0	7	4	7
12	10	1[a]	0	4[a]	74	34	35	52	26	45	20	38	18
13	10	0	3	6	56	21	21	93	52	33	30	0	0
14	10	31	39	20	35	33	30	53	26	37	28	22	20
15	10	10	7	23	23	18	8	25	23	31	31	21	18
16	10	16	16	30	0	0	0	21	13	14	43	6	5
17	10	12	8	26	6	0	11	20	31	36	16	18	4
18	10	12	7	8	9	7	7	10	5	12	13	5	7
19	10	2	0	0	0	0	2	2	2	2	2	0	3
20	10	3	2	9	10	9	7	4	2	2	2	0	3
21	14	0	66	29	33	32	17	18	17	26	33	0	0
22	15	39	29	22	61	44	29	39	34	38	66	9	17
23	15	40	50	16	14	18	44	28	26	36	34	12	14
24	15	28	35	23	26	16	16	37	21	47	35	45	12
25	15	52	61	31	52	55	26	42	28	28	49	16	17
26	15	56	34	31	48	29	29	24	24	53	48	20	29
27	15	55	76	26	34	33	26	31	22	34	30	20	34
28	15	42	35	45	37	39	19	24	31	64	42	16	35
29	15	22	28	63	32	19	25	25	0	0	0	19	35
30	15	49	38	157	88	66	29	57	73	57	71	44	49
31	15	37	21	15	9	19	14	28	13	15	10	10	10
32	15	23	31	21	10	6	4	18	9	41	23	23	23
33	15	14	16	4	0	21	6	4	23	6	9	13	4
34	15	9	24	32	31	26	15	17	24	17	12	11	19
35	15	25	28	12	35	22	18	24	23	15	11	16	18
36	15	14	15	19	7	34	44	47	39	17	32	32	7
37	20	31	2[a]	3[a]	39	29	38	28	24	12	54	40	43
38	20	32	17	44	67	51	41	35	89	39	22	18	25

[a] Section having a smooth surface , that is, an intact surface

Regarding ACMs, the density ratio (B_{ave}/I_{ave}) was 150, i.e., fiber bundles assumed to be asbestos were found on the broken surface at a density 150 times as large as that on the intact surface. There were no samples in which no fiber bundles assumed to be asbestos were found on the broken surface of ACMs, i.e., the determination error rate for observation of both the intact and broken surfaces and that for observation of only the broken surface were both 0% (Table 3). Therefore, observation of only the broken surface would obtain similar results to observation of both types of surface.

TABLE 3 ERROR RATES OF DETERMINATION BY VISUAL OBSERVATION OF INTACT + BROKEN AND ONLY BROKEN SURFACE

	Number of particles	Intact + broken	Broken
	–	%	%
non-ACMs	89	4.5	2.2
ACMs	38	0	0

Error of Determination by Visual Observation of One-half of Broken Surface

In the following, it was considered whether the results of observation of only one-half of the broken surface (6 of 12 sections) would be similar to those of observation of the entire broken surface. In the observation of 6 of the 12 sections on broken surface, the number of combinations was ${}_{12}C_6 = 924$.

There were two of 89 non-ACM samples in which fiber bundles assumed to be asbestos were found on the broken surface, i.e., the determination error rate was 2/89 = 0.022. In one sample, fiber bundles assumed to be asbestos were found on three sections. In the other sample, they were found in one section. Then, the rates in which fiber bundles were found in one-half of the broken surface were obtained. The number of combinations in which fiber bundles were found on six sections randomly chosen in the two non-ACMswas $924 - {}_{(12\text{-}3)}C_6 = 840$ and $924 - {}_{(12\text{-}1)}C_6 = 462$. From the above, the rate at which the two samples were chosen from 89 non-ACM samples and fiber bundles were found on six sections randomly chosen was (840/924+462/924)/89 = 0.016. Therefore, for non-ACMs, the determination error rate for observation of one-half of the broken surface was 1.6%, whereas that for observation of the entire broken surface was 2.2% (Table 4).

Regarding the observation of one-half of the surface of an ACM, determination error occurs when density of fiber bundles is 0 on all of the six chosen sections, i.e., samples have 0 density on six or more sections. As shown in Table 2, there were three samples (Nos.1, 2, and 4) with 0 density on six or more sections in 38

ACM samples. The combinations in which the density of fiber bundles is 0 on all of the six chosen sections in the three ACM samples were ${}_8C_6$ = 28 (No. 1), ${}_8C_6$ = 28 (No. 2), and ${}_6C_6$ = 1 (No. 4). From the above, the rate at which the three samples with 0 density of fiber bundles on all of the six randomly selected sections were chosen from 38 ACM samples was (28/924+28/924+1/924)/38 = 0.0016. There were no samples in which the density of fiber bundles was 0 on all sections in ACMs. Therefore, for ACMs, the determination error rate for observation of one-half of the broken surface was 0.16%, although that for observation of the entire area of the broken surface was 0% (Table 4). From the obtained error rates, the time necessary for observation can be shortened.

TABLE 4 ERROR RATES OF DETERMINATION BY VISUAL OBSERVATION OF ENTIRE AREA AND ONE-HALF OF BROKEN SURFACE

	Number of particles	**Entire area**	**One-half of area**
	–	%	%
non-ACMs	89	2.2	1.6
ACMs	38	0	0.16

Limitation of this Study and Future Study

Because only samples with asbestos contents of < 0.1 w% and from 7 to 20 w% were examined in this study, the discussion above is limited within these asbestos contents. Since the standard content of asbestos is 0.1 w%, as mentioned above, further investigation of the accuracy of visual observation and the feasibility of observation of a part of the surface on CDWs with approximately 0.1 w% asbestos content should be carried out. However, since ACMs often have asbestos at contents sufficient to exert its optimum characteristics (e.g., chemical or wear resistance), ACMs with low asbestos contents can hardly be obtained as samples for this type of study. Furthermore, the entire or part of a sample is destroyed during the measurement of asbestos content. The situations mentioned above make it difficult to use ACMs with low asbestos contents for studies. Further investigation is needed to improve the representativeness of samples.

In this study, determination error rates for observation of one-half of the surface of CDWs were obtained. Although the time necessary for observation was shortened by observing only one-half of the surface, further study should be carried out by simulating the observation and sorting of CDWs in order to evaluate whether the obtained error rates are acceptable or not.

Conclusions

If visual observation of asbestos fibers on a part of the surface of CDW particles could be carried out and that on other areas could be omitted, the time necessary for visual observation can be shortened. In this study, determination error rates for a certain part of the surface and for the entire surface were estimated. For asbestos contents of < 0.1 w% and from 7 to 20 w%, the main findings were as follows:

A CDW particle whose surface remained intactwhen the construction material was produced was classified as an intact-surface CDW particle, whereas a CDW particle that chipped off when the construction material was demolished or shredded was classified as a broken-surface CDW particle. Observation of only the broken surface would yield similar results to observation of the entire surfaces of non-ACMs and ACMs. For non-ACMs, the determination error rate for observation of one-half of the broken surface was 1.6%, whereas that for observation of the entire broken surface was 2.2%. For ACMs, the determination error rate for observation of one-half of the broken surface was 0.16%, whereas that for observation of the entire broken surface was 0%. From the obtained error rates, it was found that the time necessary for observation can be shortened.

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